14. Model Based Systems Engineering: Issues of application to Soft Systems

Ady James, Alan Smith and Michael Emes
UCL Centre for Systems Engineering, Mullard Space Science Laboratory

Abstract

Projects often seek to deliver new or improved capabilities within complex, poorly defined and changing contexts. The application of MBSE under such circumstances can be problematic and in this paper we discuss these issues, and suggest approaches for their mitigation.

A particular system solution might be envisaged as a combination of subsystems connected through a common architecture. Systems thinking suggests that given clear requirements and a solution concept, one can move forward through the definition of subsystem capabilities and the system architecture – where MBSE is particularly useful. However, in many applications the degree of turbulence or evolution within the requirements that can be expected means that close human intervention is necessary to keep the solution fit for purpose. Moreover, this human intervention must be based on significant experience and domain knowledge so as to cope with the many Soft System issues that are likely to be present. At University College London (UCL) Centre for Systems Engineering we propose five principles that we believe should underpin all SE development projects. In this work we discuss these principles and their application to MBSE within a Soft System context.

The UCLse principles are:

- Principles govern process
- Seek alternative systems perspectives
- Understand the enterprise context
- Integrate systems engineering and project management
- Invest in the early stages of projects

Moreover, we will also look at how encapsulation can be used to protect MBSE sub-system developments from the likely changes in scope and direction of the overall development. Encapsulation, while fundamental to an object oriented approach, is much less well developed for soft systems projects except where it manifests as a pragmatic approach taken by the systems engineer, systems engineering manager or project manager. Through an encapsulation approach one can create a system from the inside out, i.e. begin sub-system development before the final structure of the overall system is fully defined. There are parallels with a system-of-system approach in which the sub-systems pre-exist the system. Re-use and the use of Commercial-Off-The-Shelf (COTS) and Military-Off-The-Shelf (MOTS) sub-systems are natural to an encapsulated approach.

An important element of such an approach is the validation of the chosen system architecture or an estimation of its resilience. This can be undertaken through a carefully selected (and weighted) set of scenarios – the consequences of each being used to define the interface margins and architectural capacity within the overall system. This is a natural extension to the concept of requirements volatility found in requirements management tools etc.

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE **FEB 2013**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Model Based Systems Engineering: Issues of application to Soft Systems**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **UCL Centre for Systems Engineering, Mullard Space Science Laboratory**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

See also ADA585222. Proceedings of the 2012 Model-Based Systems Engineering Symposium, 27 - 28 November 2012, DSTO Edinburgh, South Australia., The original document contains color images.

14. ABSTRACT

Projects often seek to deliver new or improved capabilities within complex, poorly defined and changing contexts. The application of MBSE under such circumstances can be problematic and in this paper we discuss these issues, and suggest approaches for their mitigation. A particular system solution might be envisaged as a combination of subsystems connected through a common architecture. Systems thinking suggests that given clear requirements and a solution concept, one can move forward through the definition of subsystem capabilities and the system architecture â where MBSE is particularly useful. However, in many applications the degree of turbulence or evolution within the requirements that can be expected means that close human intervention is necessary to keep the solution fit for purpose. Moreover, this human intervention must be based on significant experience and domain knowledge so as to cope with the many Soft System issues that are likely to be present. At University College London (UCL) Centre for Systems Engineering we propose five principles that we believe should underpin all SE development projects. In this work we discuss these principles and their application to MBSE within a Soft System context.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**13**	

Finally we will look at the bounds of MBSE, where is it *not* a practical way forward and where should it be supplemented and augmented by a Soft Systems front end and concurrent activity? For instance some system capability uplifts are dominated by the viewpoints of existing participants and are often in situations where there is no single design authority. While MBSE can improve their toolset, the actual system level changes that are possible may lend themselves more to change management than MBSE.

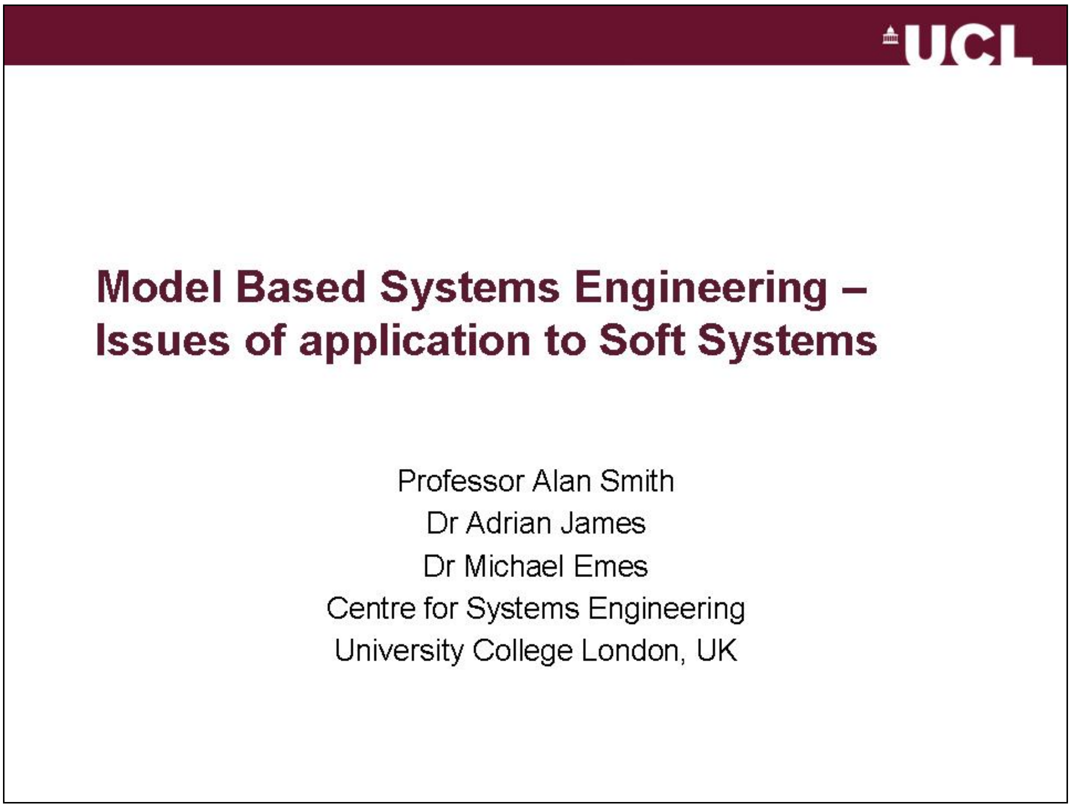
Presenter Biographies

Dr. Adrian James is a Senior Research Fellow at MSSL and Co-director of UCL Centre for Systems Engineering (UCLse). He has worked at UCL for more than twenty years on various space programmes, including Mars 96, Cluster, XMM Newton, Hinode, and most recently the ESA Euclid project. As well as his project management and systems engineering activities within the Department Dr James provides training courses to industry on various aspects of Systems Engineering and Project Management. He is now based in Adelaide as Executive Director of MSSL (Australia).

Professor Alan Smith started as an instrument scientist for the Medium Energy X-ray Experiment which flew on-board the European space agency mission EXOSAT. In 1990 he joined MSSL, initially as Head of Detector Physics but later to become Programme Manager and eventually Director and Head of Department and vice-Dean for Enterprise. In 1998 he was made a Professor of Detector Physics. While at UCL he has been Director of UCL's Centre for Advanced Instrumentation Systems, a Co-director of the Smart Optics Faraday Partnership and is founding Director of UCLse.

Dr. Michael Emes is Head of the Technology Management Group at MSSL and Co-director of UCLse. He researches technology management tools and theory, risk management, modelling, and the intersection of systems engineering and management. He teaches postgraduate courses at UCL and industrial training courses in the areas of systems engineering, design, modelling and management. Before joining UCL, Michael was a strategy consultant working on projects in retail, e-commerce and transport. He has a first-class MEng in Engineering, Economics and Management from St. John's College, Oxford, and a PhD in Spacecraft Engineering from UCL.

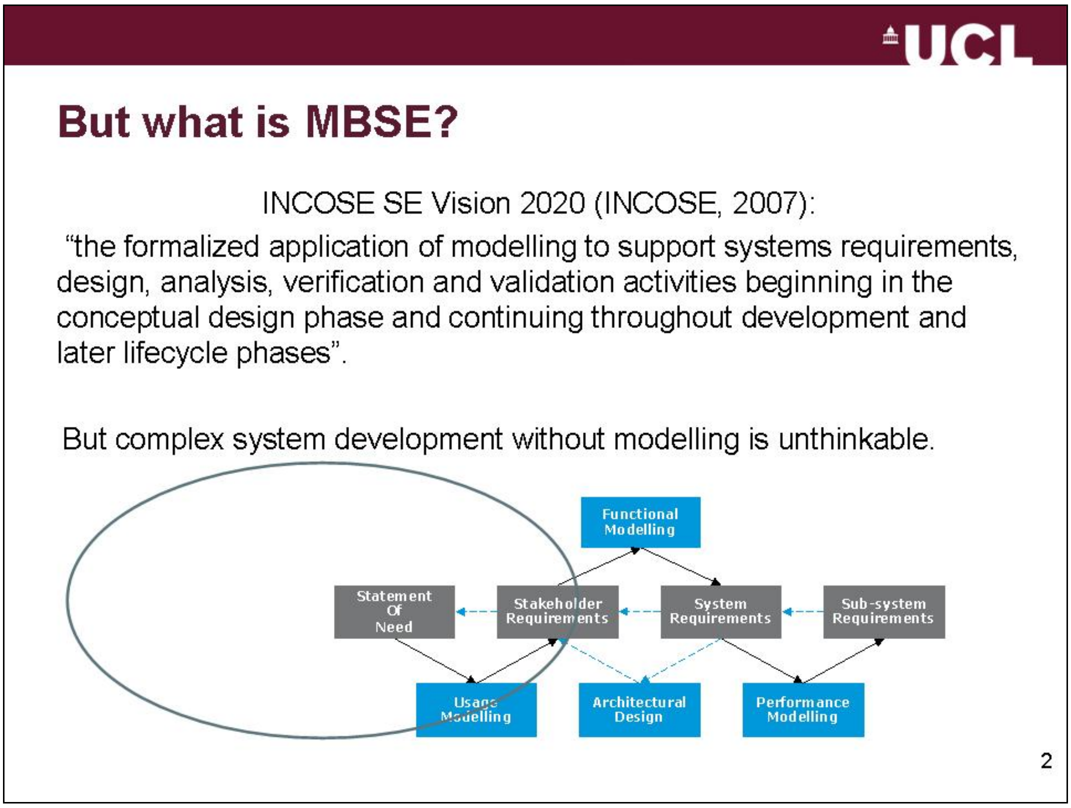
Presentation



UCL

Model Based Systems Engineering – Issues of application to Soft Systems

Professor Alan Smith
Dr Adrian James
Dr Michael Emes
Centre for Systems Engineering
University College London, UK



UCL

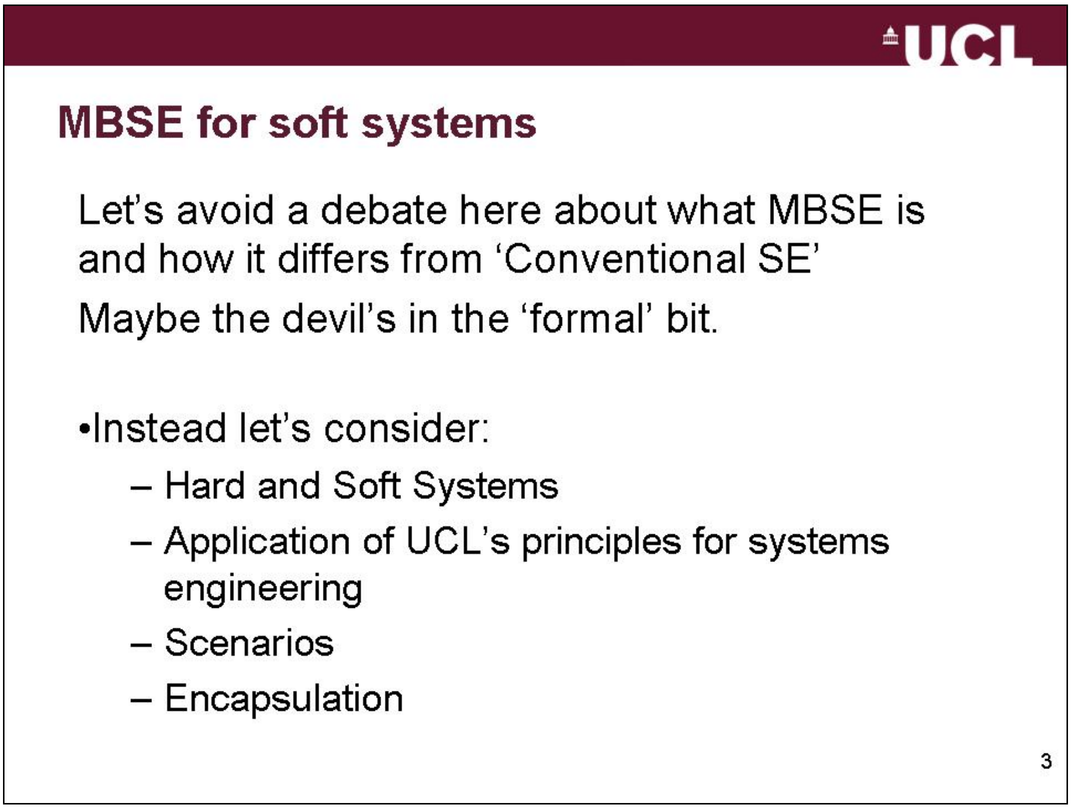
But what is MBSE?

INCOSE SE Vision 2020 (INCOSE, 2007):

"the formalized application of modelling to support systems requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later lifecycle phases".

But complex system development without modelling is unthinkable.

2



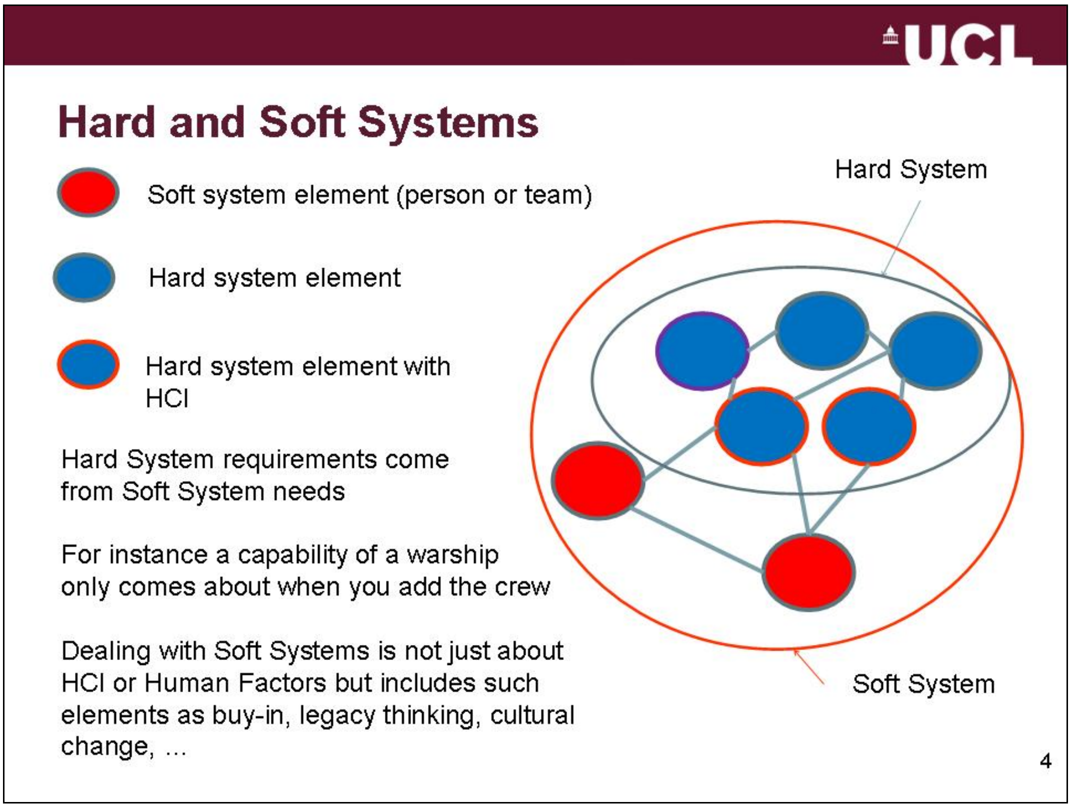
MBSE for soft systems

Let's avoid a debate here about what MBSE is and how it differs from 'Conventional SE'

Maybe the devil's in the 'formal' bit.

- Instead let's consider:
  - Hard and Soft Systems
  - Application of UCL's principles for systems engineering
  - Scenarios
  - Encapsulation

3



Hard and Soft Systems

● Soft system element (person or team)

● Hard system element

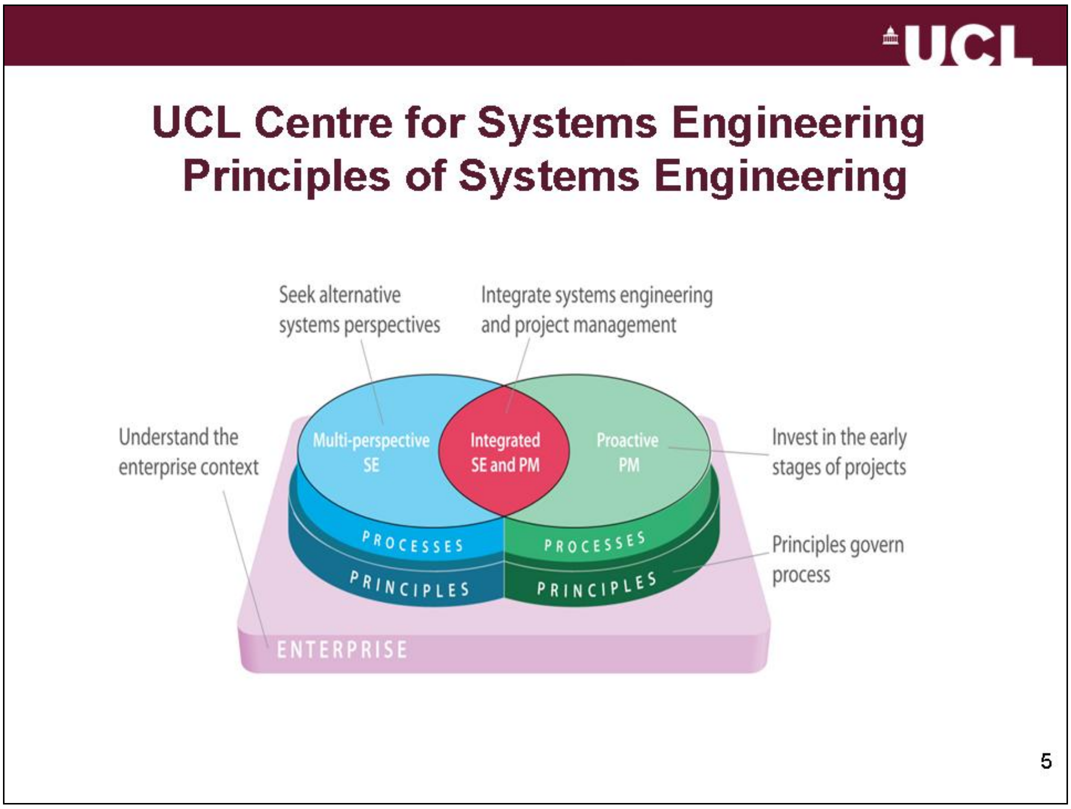
● Hard system element with HCI

Hard System requirements come from Soft System needs

For instance a capability of a warship only comes about when you add the crew

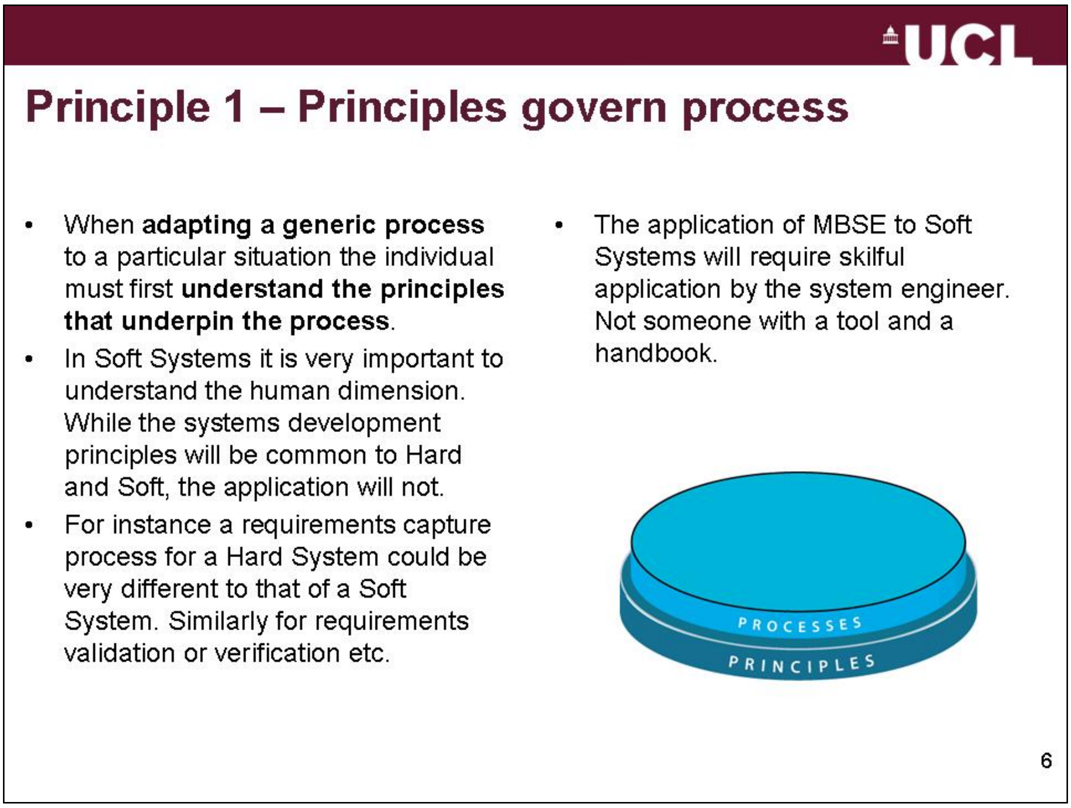
Dealing with Soft Systems is not just about HCI or Human Factors but includes such elements as buy-in, legacy thinking, cultural change, …

4



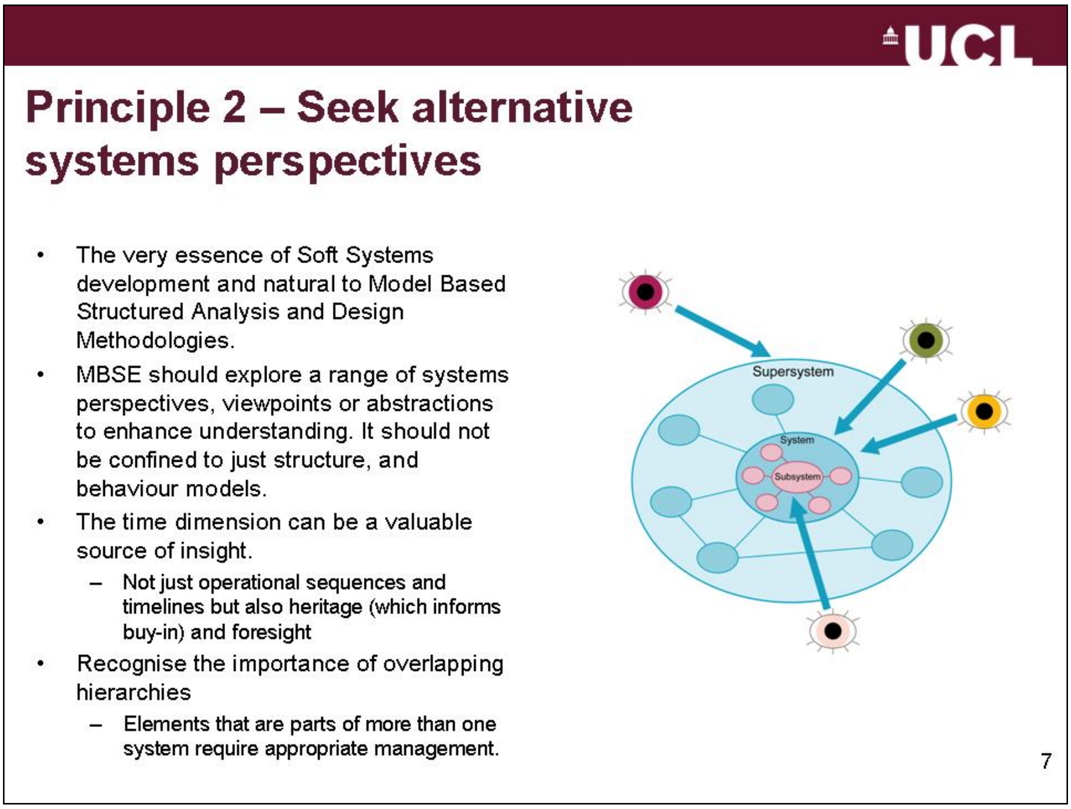
UCL Centre for Systems Engineering Principles of Systems Engineering

UCL
Seek alternative systems perspectives
Integrate systems engineering and project management
Understand the enterprise context
Multi-perspective SE
Integrated SE and PM
Proactive PM
Invest in the early stages of projects
PROCESSES
PROCESSES
Principles govern process
PRINCIPLES
PRINCIPLES
ENTERPRISE



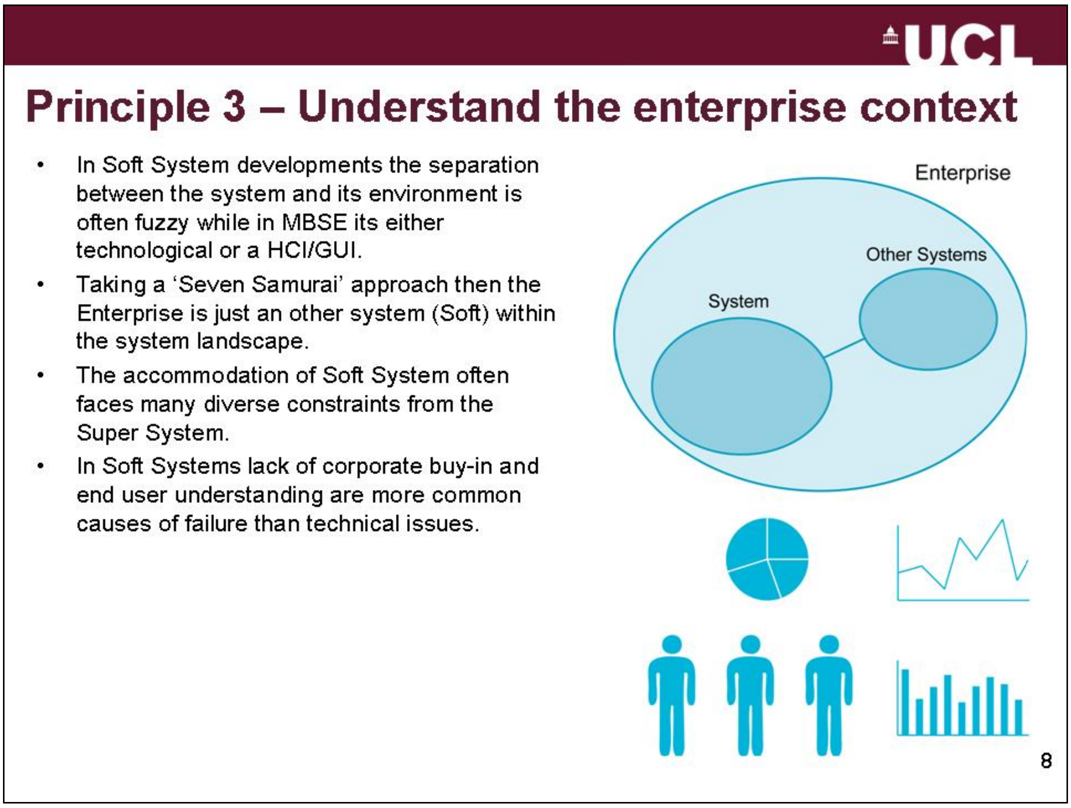
Principle 1 – Principles govern process

- When **adapting a generic process** to a particular situation the individual must first **understand the principles that underpin the process**.
- In Soft Systems it is very important to understand the human dimension. While the systems development principles will be common to Hard and Soft, the application will not.
- For instance a requirements capture process for a Hard System could be very different to that of a Soft System. Similarly for requirements validation or verification etc.
- The application of MBSE to Soft Systems will require skilful application by the system engineer. Not someone with a tool and a handbook.



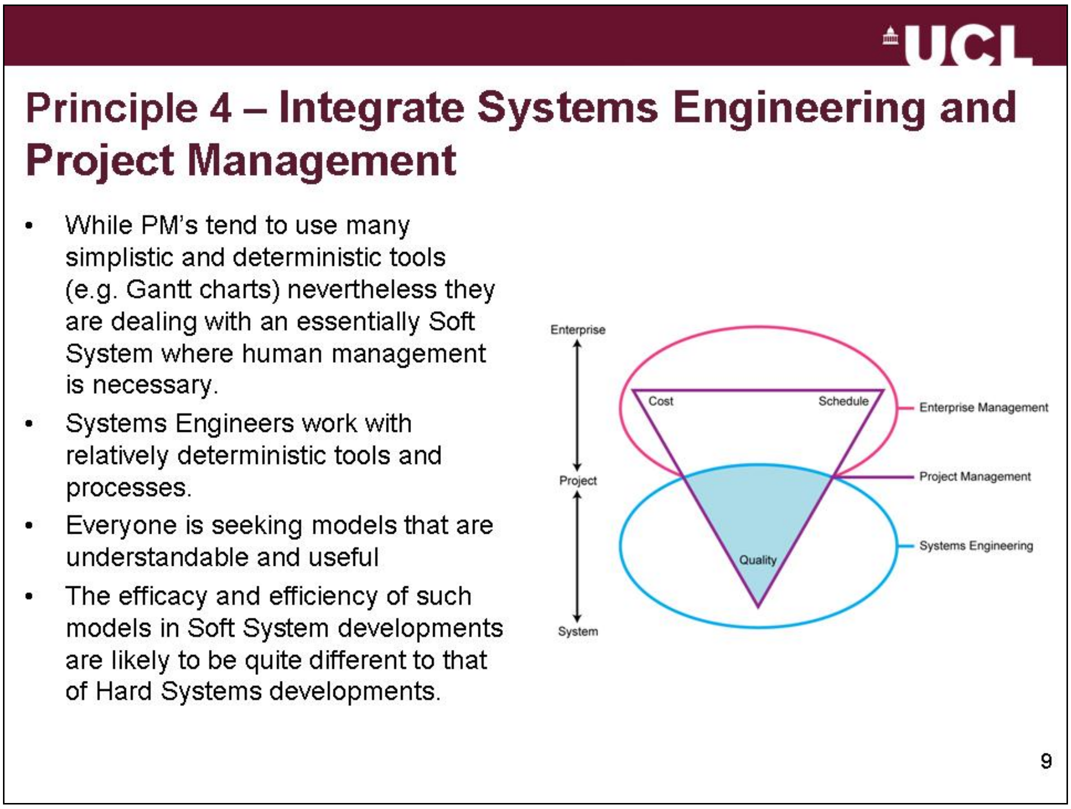
Principle 2 – Seek alternative systems perspectives

- The very essence of Soft Systems development and natural to Model Based Structured Analysis and Design Methodologies.
- MBSE should explore a range of systems perspectives, viewpoints or abstractions to enhance understanding. It should not be confined to just structure, and behaviour models.
- The time dimension can be a valuable source of insight.
  - Not just operational sequences and timelines but also heritage (which informs buy-in) and foresight
- Recognise the importance of overlapping hierarchies
  - Elements that are parts of more than one system require appropriate management.



Principle 3 – Understand the enterprise context

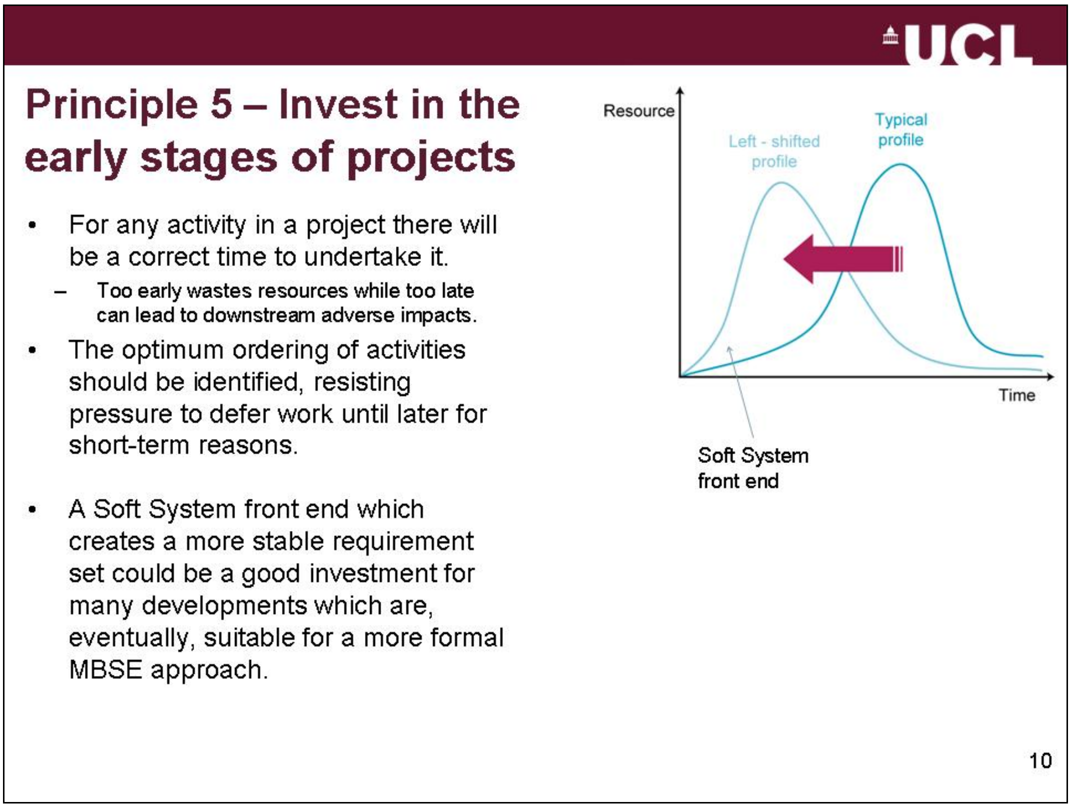
- In Soft System developments the separation between the system and its environment is often fuzzy while in MBSE its either technological or a HCI/GUI.
- Taking a 'Seven Samurai' approach then the Enterprise is just an other system (Soft) within the system landscape.
- The accommodation of Soft System often faces many diverse constraints from the Super System.
- In Soft Systems lack of corporate buy-in and end user understanding are more common causes of failure than technical issues.



Principle 4 – Integrate Systems Engineering and Project Management

- While PM's tend to use many simplistic and deterministic tools (e.g. Gantt charts) nevertheless they are dealing with an essentially Soft System where human management is necessary.
- Systems Engineers work with relatively deterministic tools and processes.
- Everyone is seeking models that are understandable and useful
- The efficacy and efficiency of such models in Soft System developments are likely to be quite different to that of Hard Systems developments.

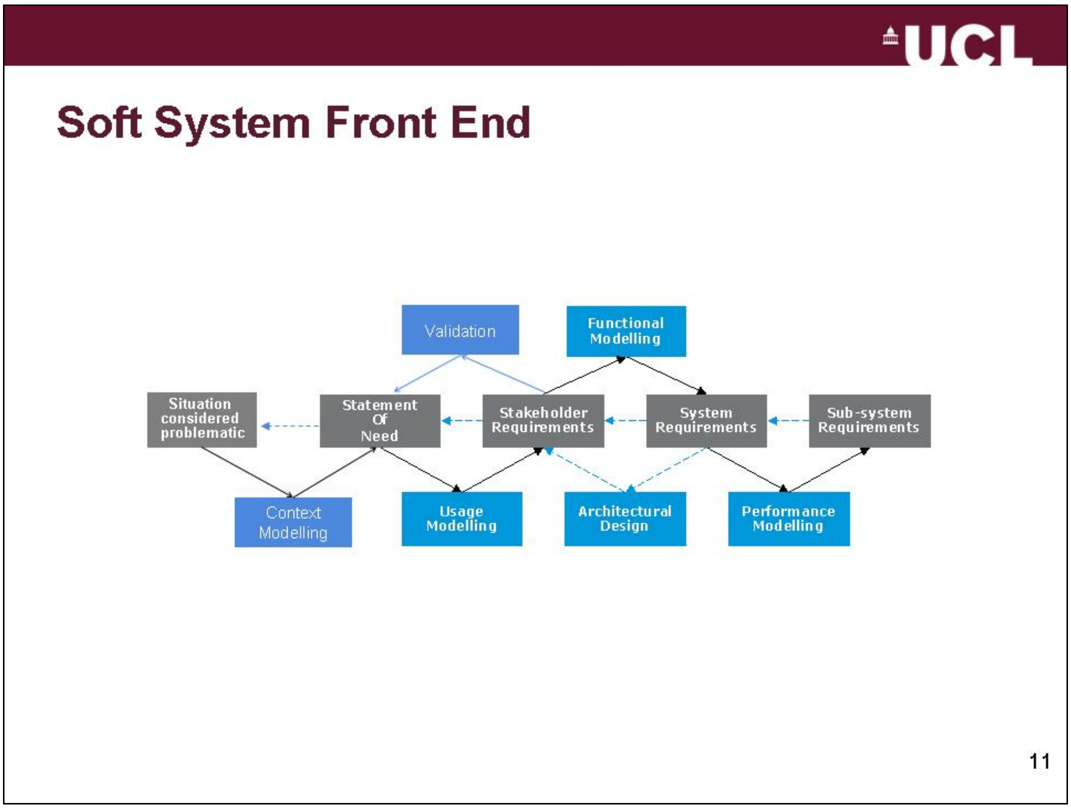
9



Principle 5 – Invest in the early stages of projects

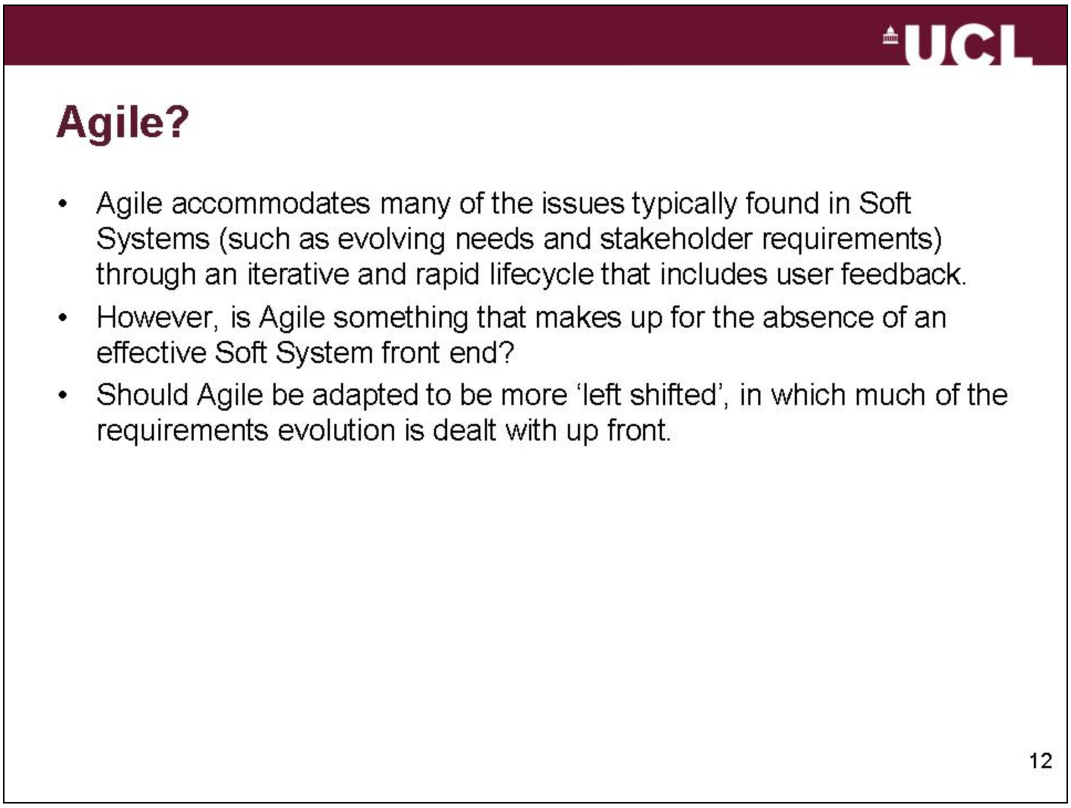
- For any activity in a project there will be a correct time to undertake it.
  - Too early wastes resources while too late can lead to downstream adverse impacts.
- The optimum ordering of activities should be identified, resisting pressure to defer work until later for short-term reasons.
- A Soft System front end which creates a more stable requirement set could be a good investment for many developments which are, eventually, suitable for a more formal MBSE approach.

10



Soft System Front End

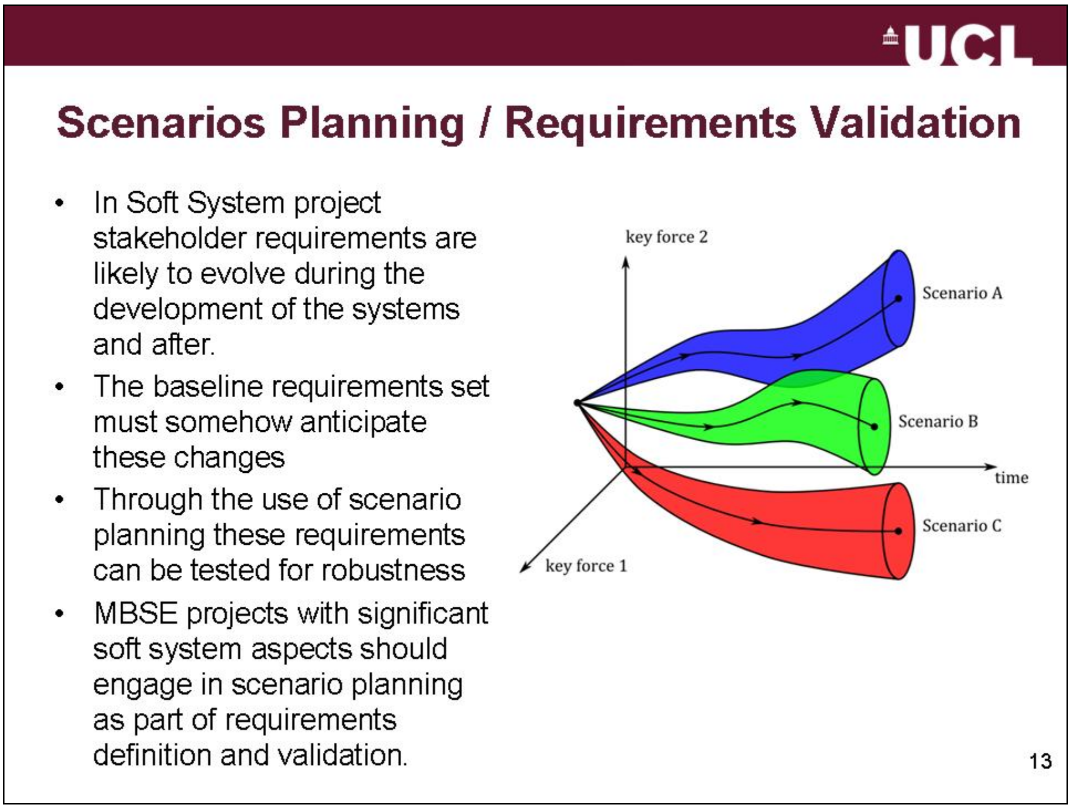
11



Agile?

- Agile accommodates many of the issues typically found in Soft Systems (such as evolving needs and stakeholder requirements) through an iterative and rapid lifecycle that includes user feedback.
- However, is Agile something that makes up for the absence of an effective Soft System front end?
- Should Agile be adapted to be more ‘left shifted’, in which much of the requirements evolution is dealt with up front.

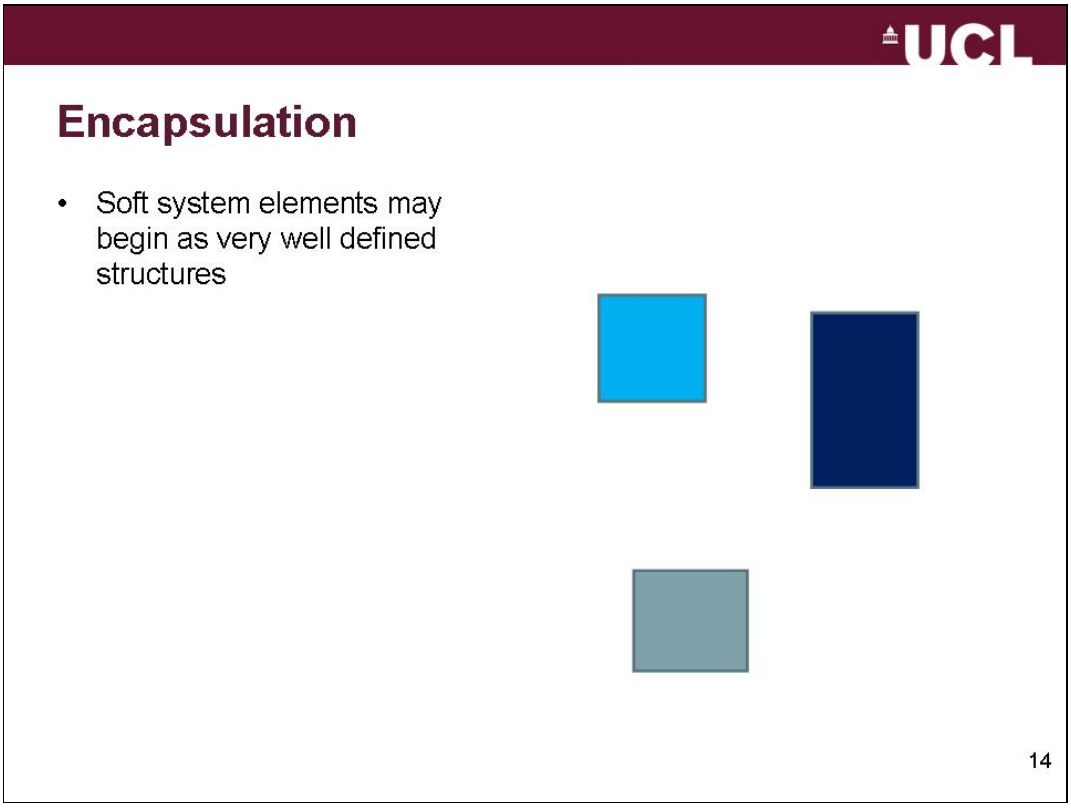
12



Scenarios Planning / Requirements Validation

- In Soft System project stakeholder requirements are likely to evolve during the development of the systems and after.
- The baseline requirements set must somehow anticipate these changes
- Through the use of scenario planning these requirements can be tested for robustness
- MBSE projects with significant soft system aspects should engage in scenario planning as part of requirements definition and validation.

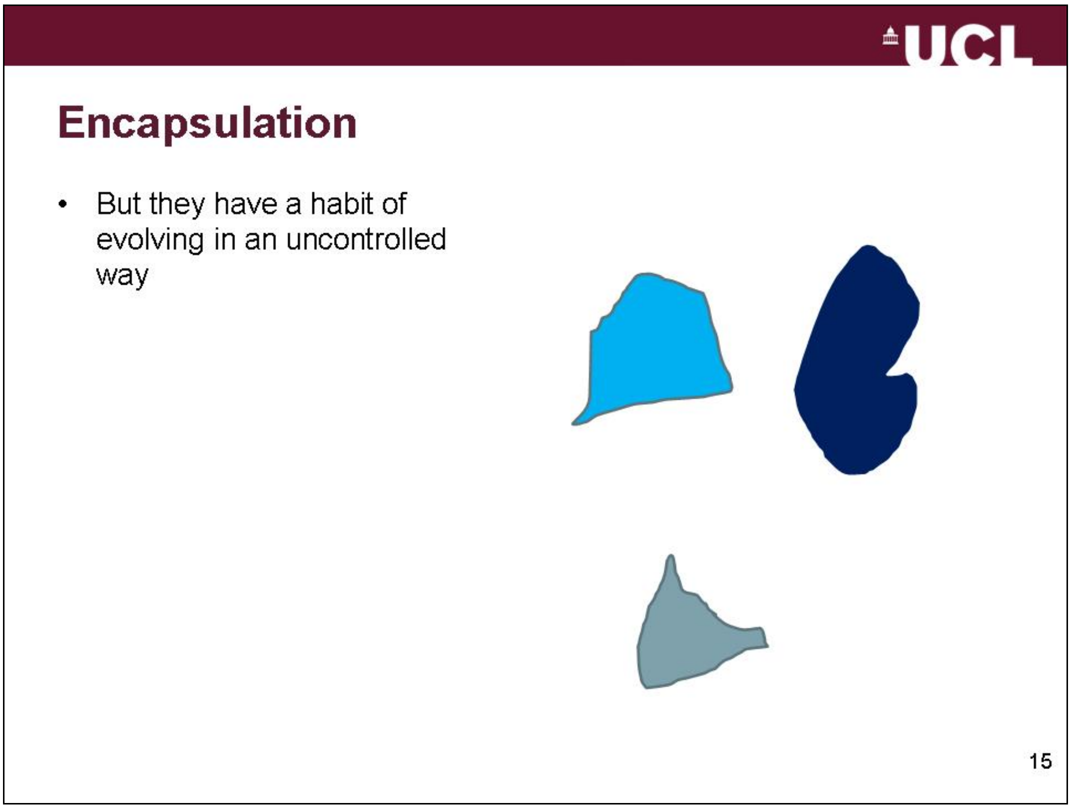
13



Encapsulation

- Soft system elements may begin as very well defined structures

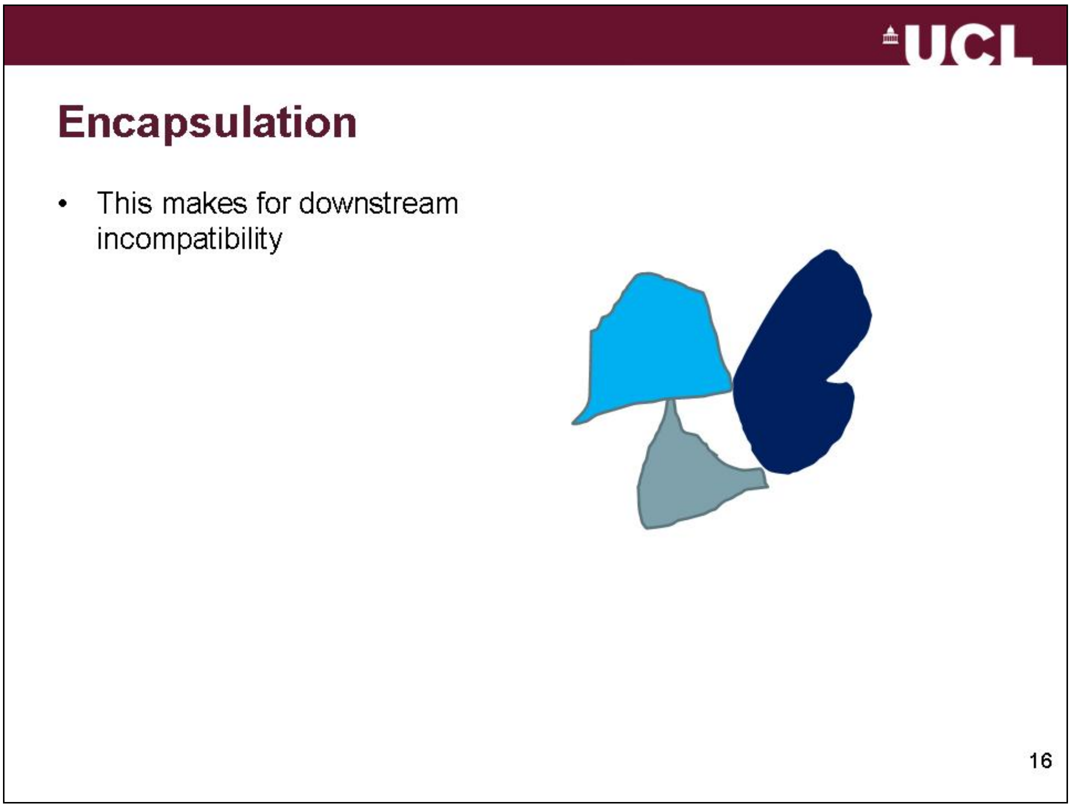
14



Encapsulation

- But they have a habit of evolving in an uncontrolled way

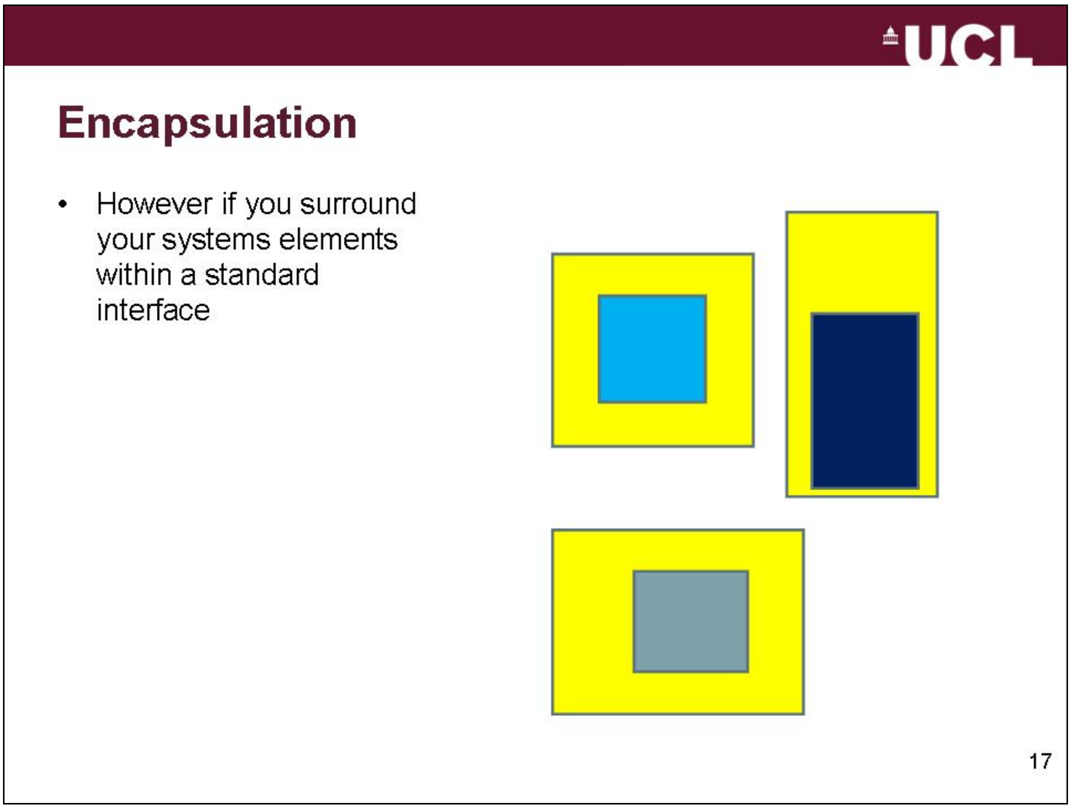
15



Encapsulation

- This makes for downstream incompatibility

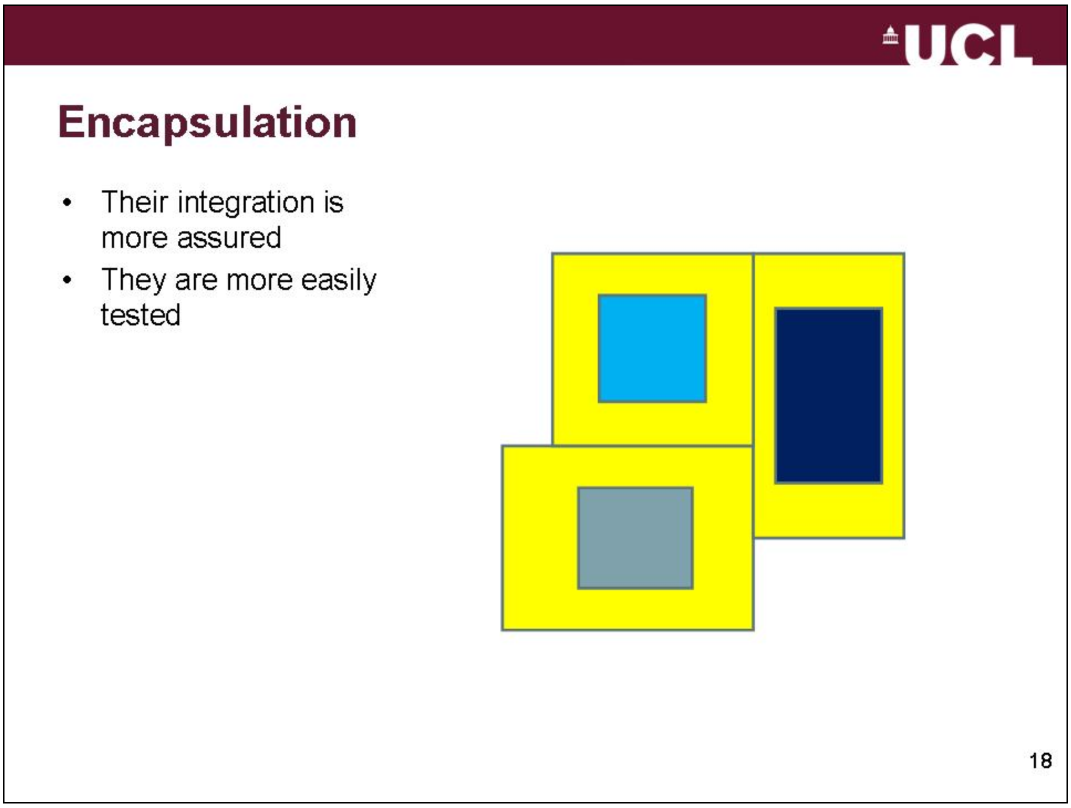
16



Encapsulation

- However if you surround your systems elements within a standard interface

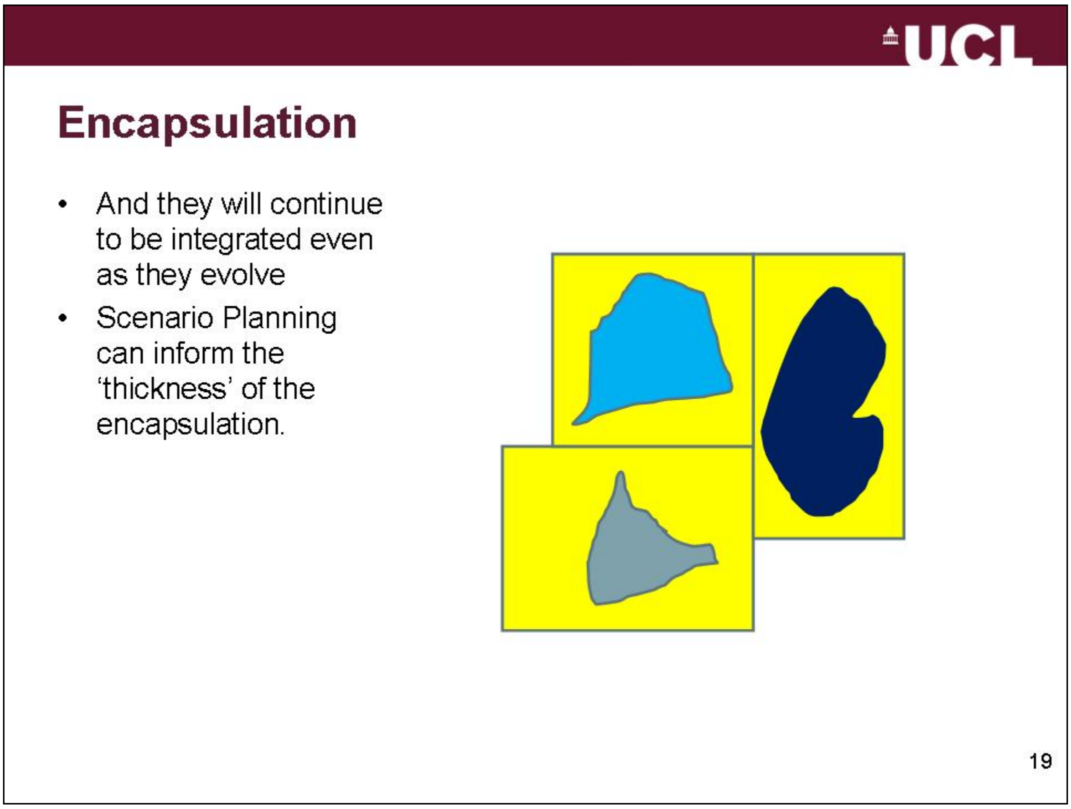
17



Encapsulation

- Their integration is more assured
- They are more easily tested

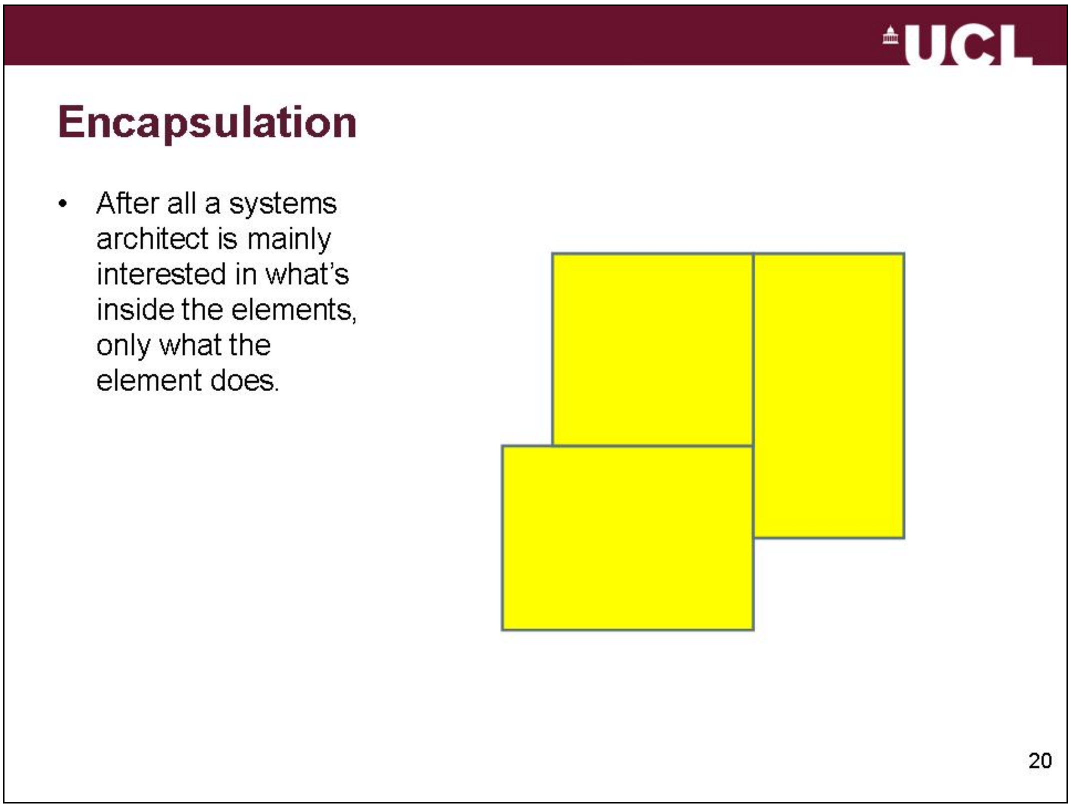
18



Encapsulation

- And they will continue to be integrated even as they evolve
- Scenario Planning can inform the 'thickness' of the encapsulation.

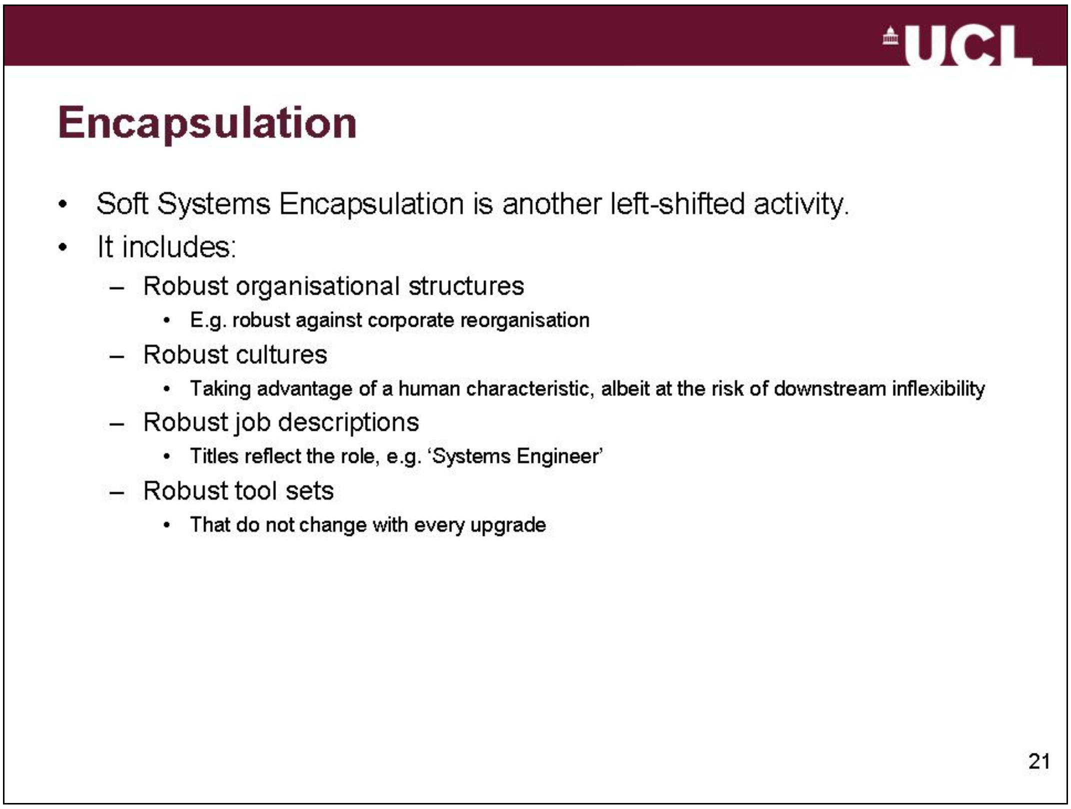
19



Encapsulation

- After all a systems architect is mainly interested in what's inside the elements, only what the element does.

20

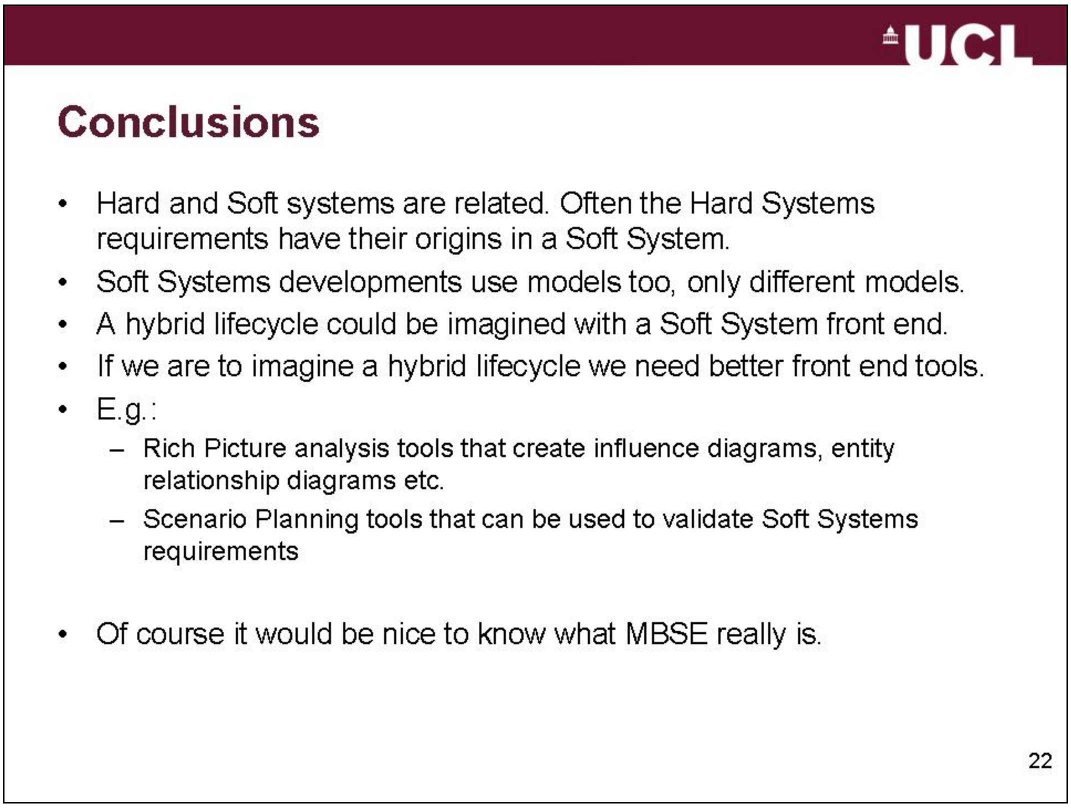


UCL

Encapsulation

- Soft Systems Encapsulation is another left-shifted activity.
- It includes:
  - Robust organisational structures
    - E.g. robust against corporate reorganisation
  - Robust cultures
    - Taking advantage of a human characteristic, albeit at the risk of downstream inflexibility
  - Robust job descriptions
    - Titles reflect the role, e.g. ‘Systems Engineer’
  - Robust tool sets
    - That do not change with every upgrade

21



UCL

Conclusions

- Hard and Soft systems are related. Often the Hard Systems requirements have their origins in a Soft System.
- Soft Systems developments use models too, only different models.
- A hybrid lifecycle could be imagined with a Soft System front end.
- If we are to imagine a hybrid lifecycle we need better front end tools.
- E.g.:
  - Rich Picture analysis tools that create influence diagrams, entity relationship diagrams etc.
  - Scenario Planning tools that can be used to validate Soft Systems requirements
- Of course it would be nice to know what MBSE really is.

22